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A study of the accuracy of reproduction of measured photography: A method to equate the tonal range of the color transparency to the tonal of the photomechanical reproduction

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A Study of the Accuracy of Reproduction of Measured Photography: A Method to Equate the Tonal Range of the Color Transparency to the Tonal Range of the Photomechanical Reproduction

by

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's Thesis of

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to the Tonal Range of the Photomechanical Reproduction

Michael Grant Scala

date

Dedication:

This thesis is dedicated to my father,

Dr. Michael E. Scala,

and to my wife,

Laura R. Bentley

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ABSTRACT

The density range of a color transparency greatly exceeds the density range capacity of reproductions with ink on paper. It is therefore necessary to perform tone compression. Traditionally, tone compression is accomplished by the color separator and involves subjective decisions without input from the photographer. Tone reproduction of the final image is a result of image manipulation by different people in production who are not in communication with each other. Consequently, image quality may suffer and important image detail may be lost as a result of improper estimates.

Measured photography is an exposure method whereby major decisions of tone reproduction are made by the photographer at the time of exposure. Additionally, the number of bracket exposures may be reduced. Finally, the scanner operator may have greater opportunity to gang-scan groups of originals.

This report examined the details of measured photography; an experiment compared the results of measured photography with those of traditional photography in terms of the uniformity between the transparency and the photomechanical reproduction.

Five photographers each made two Ektachrome transparencies of the same scene. After selecting appropriate diffuse highlight and detail shadow points from the subject, they adjusted the lighting between these points so that the difference between them was six to eight stops as measured at the film plane (equals 7.5

to 9.5 stops at the subject, with average flare of 1.5 stops). This exposure represented the conventionally exposed photograph. They then altered the lighting so that the range between these two points was reduced to three and a half to four and half stops. This matched the tonal range of the photomechanical reproduction and represented the measured photograph. Transparencies were processed normally by E-6 process.

Color separations were made with the Hell 399-ER scanner. The highlight and shadow placements were determined using the same points selected by the photographers.

Finally, five photographers and five art directors served as judges. With standard viewing conditions, they were presented with two pairs of transparencies adjacent to two separation prints and asked to select the pair which represented the closest match between the transparency and the print.

It was found that a significant number of judges selected the photographs made by measured photography as representing the closest visual match between the transparency and the print. These findings suggest that measured photography is a better method for making a transparency that more closely resembles the photomechanical reproduction. Since the transparency provides an accurate representation of how the photomechanical reproduction will appear, it eliminates the guesswork typically associated with this pre-visualization. Furthermore, measured photography allows a photographer to maintain better control of tone reproduction throughout the image reproduction process.

CHAPTER I

INTRODUCTION

Imagine the reproduction process as a chain with four links. The links represent the photographer, the color separator, the platemaker and the press operator. The chain is only as strong as its weakest link. To optimize the reproduction process, it is essential to have a co-operative effort between connecting links of the chain. Generally, the links between the final three elements of the chain are strong; the color separator, the platemaker and the press operator work together as a team. Unquestionably, the weakest communication link is between the photographer and the color separator. Although their common objective is to create an image with ink on paper, the photographer and the color separator rarely communicate with each other. Since their individual contributions are equally important to achieve maximum reproduction quality, it is not surprising that image quality may suffer. The potential of the reproduction process is not realized.

The density range of a photographic color transparency is approximately 3.0; whereas the capability of a photomechanical reproduction with ink on paper is about 1.8. Pre-scan analyzer systems are available which attempt to assist the scanner operator in decisions of tone compression. These systems assist the operator in the evaluation of the original copy. They consider the tonal range, emulsion type and exposure (under or over) and other factors. Then the pre-scan analyzer computes an optimum tone reproduction curve to match the original to the printing conditions and finally indicates set-up points to the scanner operator. These systems offer a good method of analyzing a normal transparency. However, they cannot be used to interpret the intent of the photographer. As a result, it is possible to mis-assign tone reproduction and as such, they do not solve the problems to which we address ourselves. Consequently, important image tones are sometimes lost as a result of improper estimates.

When a transparency is made specifically for reproduction and press conditions can be estimated beforehand, the density range of the photograph can be made to approximate the density range of the press sheet. **Measured photography** is an exposure method whereby major decisions of tone reproduction are made by the photographer at the time of exposure.

The benefits of measured photography are clear.

1. It gives the major decisions of tone reproduction to the photographer.

2. It extends the exposure latitude of the film and reduces the need for extensive bracketing.

3. It may allow the scanner operator to set up more quickly and may permit gang scanning of groups of originals more frequently.

The objective of this research was to provide a detailed examination and an objective study of measured photography. Finally, an unbiased experiment was made comparing the visual equivalence between separation prints and corresponding color transparencies made by measured photography vs. conventional photography. Experienced judges made side-by-side comparisons of the images and evaluated the best overall match.

This researcher first noticed the discrepancy between photographic and reproduction quality while working professionally in advertising photography. Working closely with art directors, photographs were made that "sparkled" and contained significant detail throughout the range of the transparency. Yet, when the printed samples were returned, it was evident that image quality had suffered considerably. Shadow detail was often lost and the original "snap" was missing.

A solution to the problem was impossible because each technician cycled the culpability onto another facet of production. The photographer and art director blamed the printer. The printer blamed the separator. The separator criticized the original photographs as being "too contrasty" and emphasized his own inability to "hold detail throughout".

It should be possible to improve on this system of tone reproduction. Returning to RIT and participating in the graduate program gave me new insight into the problem. Shortly after studying Color Separation with Professor Joseph Noga, a conversation I had with him crystallized concepts and focussed efforts towards this research.

Upon investigation of the literature, it became clear that little objective study had been made specifically in this area. Some literature contained misinformation and exaggerations of the effectiveness of efforts by the photographer to influence tone reproduction at the exposure stage. The design of this thesis was to provide objective research and an experiment that addressed these issues.

Measured photography is also called 4-stop photography. This term was not used in this report because of the misleading nature of the expression, as is discussed later.

Photographic Considerations: The photographer's objective is to make a transparency that looks good on a light box. Beyond aesthetic considerations, the primary technical concern is to achieve a well exposed image with good color balance. The tools and variables that he manipulates to meet these ends include shutter speed, aperture (f-stop), lighting ratios and color filters. Generally, the intent is to provide detail in all significant tonal areas in the transparency. Beyond this, no consideration is given to the printing process, the substrate to be printed on, the ink sets, dot gain, screen ruling, trapping, solid ink density or any other of the multitude of press variables which affect the reproduction. The principle consideration is how the transparency looks with back illumination. Even when it is known beforehand that the end use for the photograph is for photomechanical reproduction, the printing considerations are ignored by the photographic team.

Although it is well known that the density range of a transparency is greater than a printed reproduction can retain and that tone compression must therefore occur, the photographer rarely considers this and, as a result, loses control of the ultimate tone reproduction of the image. A better method of making photographs for reproduction surely exists.

Color Separation Considerations: The major role of the color separator in the halftone process is to act as an intermediary, helping to translate the original photograph into a form that can be utilized first by the platemaker and then by the press operator. The separator communicates directly with them by means of a color proof. Ideally, the proof is made to match the capabilities of the press and includes considerations of dot gain and solid ink densities. This is a cooperative effort.

The photographer creates a richly textured and layered image that optimizes the full tonal range characteristics of the film, which is then further enhanced with back illumination. When the "beacon of art" is proudly presented to the separator, the photographer feels little need to explain it since it speaks so eloquently for itself. At best, the photographer clasps the separator on the back with the encouragement or admonition, "Do your best, pal", glad that he did his own part to the delight of the art director, and "now it's done with, I've got five other assignments due by five PM..."

Since the density range of a normal transparency is considerably greater than can be reproduced by ink on paper, it becomes the separator's responsibility to estimate how tone reproduction should be accomplished. "The art of tone reproduction is in determining where to compress the tones and where to spread the tones, in order to emphasize the most important details...This is a selective process that requires experience and skill in reading and interpreting the original copy."[1] The general "rule of thumb" is to "compress more in the shadows than the highlights"; unfortunately, this rule fails to consider the intent of the photographer. When important shadow details are lost as a result of improper tone reproduction, the results are disappointing to everyone involved with the reproduction process.

It was hypothesized here that a better method of exposing a transparency for reproduction would be to calibrate the original transparency to the press sheet. This method is called measured photography and is a technique to expose the transparency when it is known beforehand that it is for photomechanical reproduction. It is achieved by the process of reverse engineering whereby plate/press capabilities are optimized first. It is the most logical way of determining optimization of the entire halftone reproduction process.

Benefits of measured photography to the photographer are numerous as have been outlined. It allows him to make major decisions concerning tone reproduction. Also, the photographer profits by an increased exposure latitude, hence will need fewer bracket exposures. Additionally, the color separator gains an advantage. Since the density range of transparencies are consistent and predictable from one transparency to another, it may allow the scanner operator to pre-set the scanner and avoid individual set-up for every photograph. With measured photography, it may be easier to gang scan images, saving considerable set-up time and expense.

Finally, it was postulated that measured photography might allow better pre-visualization from the color transparency of the printed reproduction. The research question of this report was: does measured photography provide a superior visual match between the transparency and the printed reproduction than does conventional photography? This investigation involved an experiment which specifically examined this speculation about measured photography.

Endnotes for Chapter I

1. Eastman Kodak Company, "The Color Separation Scanner", Graphics Marketing Division", 1981, p. 12.

CHAPTER II

THEORETICAL BASIS FOR THE STUDY

By itself, measured photography does not produce better reproductions. However, by shifting the responsibility of tone compression decisions to the photographer, it compels the photographer to consider the tone reproduction of the printed sheet. In this sense, measured photography allows better handling of tone reproduction and may ultimately result in better reproduction prints.

Tone Reproduction and Tone Compression: Color transparencies may be thought of as "non-reproducible originals". This is due to the fact that a normal transparency typically has a maximum density range of about 3.0, whereas the maximum density range of the press sheet is on the order of 2.0 (see Figure #1 and # 2).

One way to separate such an extended range original would be simply to truncate one end or the other, or both. This is not a good solution, unfortunately, because the resulting reproduction appears to lack shadow and/or highlight values.

Another solution is to take the two points representing the extreme ends of the density range in the original, and to assign to them dot sizes representing the extremes of our printing process, for example, 5% and 95% dot sizes. Doing so, accomplishes tone compression proportionally between these two values. This, too, has not provided aesthetic images. "The human eye does not respond equally to density differences in the light and dark areas of the picture."[1] In fact," the human eye is more sensitive to density differences in the highlights and upper mid-dletones than it is the shadow areas."[2] It is for this reason, that we reject linear tone compression and favor tone compression which is more compatible with our visual system. "The standard procedure for adjusting tone compression is to compress all the tones, but more in the shadows than the highlights."[3]

The problem with this procedure is that it is only qualitative. It does not quantitatively define how much compression should occur and where. Every original image represents a new challenge to the separator who must decide where tone reproduction should occur and how. Among the variables of the original he must consider are density range, exposure level, color cast, keyness, and many other press-related considerations. He must also adjust for press characteristics such as dot gain, trapping, magnification, and a host of other variables.

"The scanner operator must select the most important details in the original and make the halftones reproduce that information while sacrificing detail in areas less important to the storytelling."[4] Without communication as to the priority of the tonal areas, the separator is forced to guess where the important tonal areas are and to make decisions of tone reproduction based on these guesses. As a result, the reproduction is often a disappointment to the photographer who feels it should more closely match his transparency. The fact is that the photographer lost control of the image when he handed it to the separator without comment.

There is a better way to approach the problem. When it is known beforehand that the transparency is being shot for reproduction, it is possible to estimate the density range of the printed reproduction. This will depend on the printing process used (lithography, gravure, flexography), the substrate (coated, uncoated, absorbency, color and reflecting qualities), the quality and characteristics of the inks set (color strength, opacity, gloss) solid ink densities, trapping characteristics, screen ruling and other press variables. In any case, if the approximate density range of the reproduction is known beforehand, it gives the photographer an opportunity to control the tone reproduction which he did not have before. By exposing so that the density range of the transparency is equivalent to the density range of the printed reproduction, the photographer controls tone compression. In effect, the photographer approximates the "ideal" forty-five degree slope of the tone reproduction curve. Theoretically, this will provide a better visual match between the transparency and the separation print.

Controlling the Density Range of the Original: There are several ways that a photographer can control the density range of the transparency.

The gamma of transparency film is much higher than for negative materials; generally, it is from 1.8 to 2.0. By reducing the slope of the midtone portion of the characteristic curve we can effectively reduce the density range of the transparency. One method to accomplish this is by flashing the film. "A flash exposure is a supplementary exposure to non-image forming light for the purpose of altering the density or contrast of an image."[5]

Before the advent of electronic scanners, process camera operators used this technique to alter the density range of color separations to adjust for copy density range differences. The effect was to boost the shadow contrast with a non-image exposure. This technique could also be compared to camera flare in that it alters contrast by affecting the shadows areas more than other areas.

The effect of flashing film is to shorten the available density range of the film. The fogging exposure proportionally affects the shadow areas more than the highlight areas. It thus alters the shape of the characteristic curve. The flash exposure can be made before or after the main exposure.

This method, however, does not allow the photographer better control of tonal placement. Also, flashing film requires scrupulous control of the flash exposure and if not exact, tends to affect the color curves disproportionately resulting in crossed curves and undesirable color shifts.

Another way to alter contrast is by the combined manipulation of processing and exposure. In order to decrease the density range of the transparency, film is overexposed and underdeveloped. Underdevelopment modifies the shape of the curve, flattens it and affects a contrast reduction throughout the image range. Overexposure compensates for the extreme loss of shadow separation which is a result of the underdevelopment. This moves the minimum exposure point higher up on the toe and allows shadow areas to carry some tonal separation.

This approach has three disadvantages. Firstly, the photographer loses precise control of the tone placement. Secondly, underdevelopment may affect the three color curves disproportionately. The effect of this may result in an overall color shift, or a color shift in one area of tone reproduction, (for example in the shadow areas). Thirdly, highlight contrast suffers. As the highlight tones slide up the curve onto the shoulder, they become washed-out and without contrast. Also, processing labs are generally unfamiliar with this technique and may not offer underdevelopment.

The third way to control contrast is to modify the subject tonality. Elimination of subjects that are at the extremes of the contrast range will reduce contrast. This is the approach taken when photographs are composed by high key and low key subjects. The proverbial picture of the polar bear on snow in a blizzard is a good example of a limited subject tonal range. This approach may not be possible in real situations where subject requirements and layout considerations are prohibiting factors.

Another approach to reduce the contrast range of the original transparency, suggested by Dr. L. Stroebel, is to utilize transparency duplicating film. The characteristic curves of these films provides a significantly reduced slope than is characteristic of normal camera films; this indicated that they might provide an effective method to lower the contrast range of the original. Eastman Kodak offers the film in a variety of formats, speeds and balanced for different light sources.

Kodak Publication Number E-38 suggests that the Ektachrome duplicating film 6121 can be used "as a camera film for copying color reflection materials." It is balanced for tungsten exposure and is recommended for exposure times of ten seconds. Discussion with professional photographers who have used this film in camera for reproduction of fine art confirms this claim.

The final approach that a photographer can take for tone range reduction is by the modification of the luminance ratio. This is the primary method used in measured photography and it allows a photographer the greatest flexibility and control of tone reproduction. This was the independent variable in this study.

Lighting ratios are altered by: changing the relationship between the main and fill lighting, physically altering the distances of the lighting to the subject, using diffusion screens and adding fill cards and additional lighting. The experienced photographer can visually determine ultimate tone placement with the appropriate lighting control. Light meter readings allow a more accurate determination of tone placement.

Specifically, meter readings are made at the extreme highlight and shadow areas where detail is desired. The lighting is adjusted until the density range is reduced to the desired limits. These points will have been predetermined beforehand to co-ordinate with optimum printing characteristics.

In summary, tone compression must occur at some point in the reproduction process. Measured photography is a method that allows the photographer to make the important decisions of tone reproduction. By doing so, the photographer relieves the scanner operator of these decisions which otherwise are made according to his best guess. Thus the photographer maintains better control of the photograph throughout the reproduction process.

Example: It is known beforehand that lithographic printing conditions using specified paper and ink will result in a density range of 1.8. (This range will, of course, vary considerably depending on printing methods, papers, inks and other press conditions). It is also determined that the film processing conditions are maintained to produce a gamma of 1.7. Therefore:

$O = P / G$, thus, $O = 1.8 / 1.7 = 1.06$

where O = density range of the transparency, and G = gamma, and P = density range of the printed reproduction.

O is a density measurement. In order to convert this to an illuminance ratio, for measurement at the film plane in terms of f-stops, the conversion formula is used;

$I = O / 0.30$, thus, $I = 1.06 / 0.30 = 3.53$ stops

This will correspond to the range from diffuse highlight to detail shadow as measured at the film plane. Tones falling outside the range will not reproduce with tonal separation. By controlling the lighting, the photographer can place all the important tones of the scene into this range. He does so by carefully metering highlight and shadow areas and adjusting lighting until this is accomplished. Metering at the film plane accounts for the effects of optical flare.

Optical Flare: Flare was an important consideration in this experiment. Flare is "non-image forming light in a camera ...due to the reflection of light from lens surfaces, interior surfaces of the (camera) causing an overall or local decrease in contrast and increase in illuminance of the film plane."[6] Factors that affect flare are, lighting conditions, subject characteristics, lens and camera design, and dust.

In the ideal optical system, there would be "a direct proportion between the subject luminance and the image illuminances...However, at any point in the image plane of a camera, the illuminance is a result of two different sources: 1. the illumination focused by the lens and projected to the film plane, which constitutes the image-forming light; and 2. light that is the result of single and multiple reflections from the lens surfaces, diaphragm, shutter blades and additional interior surfaces of the camera, providing an approximately uniform illuminance over the whole image area. This second source of light is referred to as flare light, or simply flare and provides non-image forming light."[7]

The visual result of flare is a reduction of the image contrast. Flare increases the illuminance over the entire image area but it is most discernible in the shadow areas. The reason for this has to do with proportionality. For example, if the subject luminance ratio is 150:1, a single unit of flare introduced by the optics results in an image luminance ratio of 151:2 (or close to 75:1). This has nearly halved the illuminance ratio from the scene to the subject, and has doubled the level of the shadow illuminance while resulting in an insignificant change in the highlight areas.

Flare factor is calculated thus:

$F = L / I$, where F is the flare factor, L is the luminance ratio of the subject and I is the illuminance ratio. If flare could be totally eliminated, the flare factor would be 1.0. The normal flare factor is "approximately 2.5 under typical conditions."[8]

Continuing with the example on page 17, An average flare factor of approximately 1.5 stops added to the 3.53 stop range for the illuminance range yields a subject luminance range of 5 stops.

Normally, the flare factor is not accounted for by the photographer who takes meter readings at or from the subject. For the method of measured photography, however, flare represents an additional element which must be closely monitored. The objective in this experiment was to control the density range of the transparency so it was necessary to consider the effects of flare at the film plane. This was done using a film plane meter which measured reflected light from the scene as well as the effects of flare introduced by the lens and camera system. It provided precise control of the illuminance range of the image.

Exposure Latitude: An additional advantage, an extra dividend, is gained by the reduction of the illuminance range. When exposures are made according to measured photography, the exposure latitude of the transparency material becomes greater.

Exposure latitude is defined as "the permissible change in camera exposure, usually expressed in stops, without significant effect on image quality. The change is affected by the definition of image quality, the usable extent of the characteristic curve, and the subject illuminance range (contrast)."[9]

The best way to describe this benefit is with a brief description of useful log exposure range. "One of the most important measures of the sensitometric properties of the film is the useful log exposure range. This is the range of log exposures over which the emulsion can produce adequate separation of densities and is based on the minimum slope required to achieve it."[10] This range is calculated as follows:

1. Determine the minimum useful density - "Experiments using pictorial subjects indicate that the minimum useful point in the toe occurs where the slope is not less than 0.20 (this refers to the slope of the line tangent to the point on the toe)."
2. Determine the maximum useful density - Dr. L. Stroebel indicates that this is a point on the shoulder, where the

slope is 0.20.

3. Determine the useful log exposure range - this is represented by the distance between the two above points on the horizontal axis.

Normally, photographers use as much of the useful log exposure range as possible. Measured photography purposefully limits the use of this range. By excluding the extreme ends of the useful density range, and making an exposure only on the center portion of the characteristic curve, the exposure latitude is increased. Effectively, this means there is a greater amount of exposure variance permissible without deleterious effects. Slight overexposure or underexposure is apparent as slight but tolerable density differences; but the overall contrast is not affected. The log exposure range shifts along the straight line section of the curve, but fails to fall into the toe or the shoulder where contrast would decrease.

In practice, photographers make a series of exposures (bracket exposures) based around an optimum exposure level. This series of increasing and decreasing exposures is an effort to insure success - in fact, it is an attempt to select the optimum usable log exposure range for the subject, lighting, processing and film conditions. Variations in these conditions require extensive bracketing when the exposure latitude of the film is narrow. This is always the case with color reversal films. Thus, when using measured photographic methods, the photographer may reduce the number of bracket exposures.

Adopting methods of measured photography requires a new interpretation of original transparencies. If the photographer and art director are willing to make this adjustment, they will have better management of tone reproduction. Ultimately, this new interpretation may provide a better method of pre-visualizing the printed reproduction. When photographers use measured photography, they are creating color transparencies that closely adhere to the "ideal" forty-five degree slope of the tone reproduction graph. A color transparency made by measured photography might be termed a "WYSIWYG" image (what you see is what you get); theoretically, it is a closer approximation of the printed reproduction than a conventionally exposed transparency. This theory was scrutinized in the thesis and the experiment tested this speculation.

Endnotes for Chapter II

1. Yule, J. A., Plotting Tone Reproduction Curves, GARC.

2. IBID.

3. Southworth, Miles, "Quality Control Scanner", Vol. 5 #8, p.1.

4. Eastman Kodak Company, "Color Separation Scanner", Graphics Marketing Division, 1981, p. 12.

5. Stroebel, L. and Todd, H., Dictionary of Photography, Morgan and Morgan, New York, 1971, p. 76.

6. Stroebel. L. and Todd, H., Dictionary of Photography, Morgan and Morgan, New York, 1971, p. 76.

7. Stroebel, L. et al., Materials and Processes of Photography, Focal Press, 1986, p. 359.

8. Stroebel, L. et al., Materials and Processes of Photo-

graphy, Focal Press, 1986, p. 360.

9. Stroebel, L. and Todd, H., Dictionary of Photography, Morgan and Morgan, New York, 1974.

10. Stroebel, L. et al., Materials and Processes of Photography, 1986, p. 47.

CHAPTER III

REVIEW OF THE LITERATURE

There is a lack of authoritative literature directly concerning measured photography. Perhaps the most widely read literature is distributed by Sinar, a manufacturer of cameras and lighting equipment. Although these reports are well written and convincing, the thrust of the brochures is geared toward selling light meter equipment. The most important comment from the summation concerns the unique qualities of their through-the-lens metering system. Whenever the object of an experiment is to produce results which are used to sell a product, the veracity of the experiment is questionable. It is inevitable that experimental biases might be designed into the work and both the reliability and validity of the test results become suspect. Such research does not produce an objective assessment of the variables in question.

Other information concerning photography for reproduction all but ignores the possibilities of measured photography. Even the respected reports from Miles Southworth, "Quality Control Scanner", only recently mention the benefits of a system of measured photography.

Volume 7, Number 12 (December 1987) contains the first mention of measured photography. "Cal Newby reported on his committee's work to establish input copy specifications...The committee on input copy has suggested that a four stop range is appropriate." In his issue concerning optimum photographs for reproductions, no mention is given to the concept, need or implementation of an abbreviated tonal range. "Contrast of the picture images is particularly important when separations are to be made. Slides for reproduction should have open tones. The highlights should not be overbright, and there should be no deep shadow areas that may block up in the separations. Lighting ratios can influence the contrast and density range."[1]

Norman Sanders otherwise excellent book, Photographing for Publication, makes no mention at all of measured photography. His closest comment about original transparencies is, "their extended color gamut and range, which makes them so dynamic, are far beyond those of printing. Consequently, only experience can provide the ability to evaluate the potential of a given transparency for reproduction."[2]

The most thorough report of measured photography to date is not a technical report, but a discussion about several publishers and photographers who have experimented with the method. In "Step-By-Step Graphics", Simon Dumenco has collected comments from industry and suggests that implementation of measured photography has reduced costs. "Twenty-five percent savings in color separation and etching charges; turnaround time for every set of scans reduced by three days; and forty-five percent savings in black-and-white darkroom printing time ... tremendous amount of consistency."[3] A serious problem with this article is that the reports seem exaggerated and create the impression that measured photography represents a panacea; that when images made by this technique are reproduced, the printed results are significantly improved. There is simply no clear evidence to support this claim.

The earliest suggestions of measured photography in the literature were published in 1984 by Gerhard Muhleback in Switzerland. He reports, "As long as you know how the pictures are to be used already when they are commissioned, you can plan to make them ideal for their purpose. So the assignment should define the point of the pictorial message, and the technical process considerations (paper, screen ruling, general quality requirements). By matching your approach and technique to these points, you make your real contribution to the whole job - from exposure to the final printing."[4] Muhleback goes further to suggest that "the density range of the transparency should not exceed 2.55 and that the film plane luminance ratio should be 5 E.V."[5]

General acceptance of measured photography has been limited. The absence of unbiased information about the methods and the lack of scientific experiments concerning the visual appearance of reproductions made from measured photography have discouraged art directors from specifying measured photography. This report has attempted to fill this information gap and to encourage more research and practical use of the method.

Another reason for the general lack of interest in measured photography may be that photographers are reluctant to include measured photographs in their portfolios due to their limited density range. One alternative might be for the photographer to make two transparencies - one for viewing and a second for reproduction. There is no simple solution to this dilemma.

It is notable that the Zone System, used extensively in black and white photography, is similar to measured photography. The objective of the Zone System is to make a negative that fits the normal contrast range of printing paper. For photographers familiar with this approach, measured photography is immediately acceptable.

Endnotes for Chapter III

1. Southworth, Miles, "Quality Control Scanner", Vol. 7, #3, p. 1.

2. Sanders, Norman, Photography for Publication, R. R. Bowker, New York, 1983, p. 100.

3. Dumenco, Simon, "Step-By-Step Graphics", September, 1989, p. 78.

4. Muhleback, Gerhard, Sinar Publication # 25, p. 4.

5. IBID.

CHAPTER IV

STATEMENT OF THE PROBLEM

Many years of experience are required before photographers and art directors are capable of accurately predicting the visual appearance of the printed reproduction from the color transparency. Even highly experienced professionals may have difficulty pre-visualizing the printed results from a transparency due to scanner operator inconsistencies. The author contends that any procedure that provides a more accurate visual correspondence between the input copy and the reproduction represents a significant improvement to the overall process.

Measured photography provides several significant advantages which have been outlined. Theory indicates that this technique will also provide a more correct visual match between the input transparency and the printed reproduction. The experiment focused on this premise and specifically addressed the following issue.

HYPOTHESES

A color transparency made by measured photography will produce a closer visual match between the transparency and the color separation proof than between a conventionally made transparency and color separation proof.

LIMITATIONS OF THE STUDY

Measured photography represents a technical solution to a problem; it largely shifts the responsibility of tone reproduction from the color separator to the photographer, who is usually better acquainted with the goals of the art director. A pre-requisite is the technical competence of the photographer and a willingness to re-adjust established patterns of pre-visualization. At the camera, it involves more careful attention to illuminance ratios and may involve more time adjusting lighting equipment to obtain proper tone placement. It also necessitates a change in the perception of the transparency. Clearly, photographs made by measured photography may appear less contrasty when viewed on an illuminator. Art directors, as well as photographers will need to adapt to a new way of viewing transparencies.

Another limitation involves scenes where contrast is desirable in both the extreme highlight and extreme shadow areas of the original at the sacrifice of midtone detail. The photographer cannot control these tonal areas as well as the scanner operator. With proper selection and use of the five aim points, the scanner operator can better achieve this type of tone reproduction.

Measured photography is a studio technique which involves controlled conditions of lighting. It is clearly not intended for use by the casual photographer. Nor is it likely to be useful for outdoor scenes where natural light predominates. As the term implies, it must be known beforehand that the photograph is being shot for reproduction and some approximations of press conditions must also be known.

CHAPTER V

METHODOLOGY

Summary of Experimental Procedures

Five different photographers each made two photographs of one test subject. Each photographer exposed the test subject with normal conditions defined by an illuminance range of six to eight f-stops, as measured at the film plane between selected diffuse highlight and detail shadow points. This corresponds to 7.5 to 9.5 stops at the subject with an average 1.5 stops of flare. For the second exposure, the lighting was modified until an illuminance range of 3.5 to 4.5 stops was achieved for the same two points. Also, a polaroid, or acetate overlay was made of the scene, with marks clearly indicating the selected highlight, shadow and midtone points. Attempts were made to keep other variables constant.

The transparencies were delivered to the author and processed together with normal E-6 conditions. Color separations were made of each transparency using the aim points indicated on the polaroid or overlay.

Ten experienced judges were instructed to view each pair of halftone images under standard viewing conditions as specified by ANSI. They viewed two pairs of images at a time; the conventional transparency paired with its separation print as well as the transparency made by measured photography paired with its reproduction. They were then asked to select the pair which reflected the closest match between the transparency and the separation. Responses were recorded on a tally sheet.

A chi square test of homogeneity, with an alpha level of 0.05, was used to determine if the hypothesis was rejected or supported.

Test Images: The test objects included a variety of tones and colors to aid the judges in the evaluation. Some objects included memory colors so that later evaluations would be facilitated. A model was included in most images to portray the reproduction of skin tones.

Inclusion of a reflection gray scale was important for this study and was incorporated as part of the Kodak fourteen step reflection gray scale or the MacBeth color chart. Prominently displayed, it allowed for accurate visual comparisons. It also served to indicate aim points to the color separator.

Film type: Two types of transparency film predominate the photography industry: 1. E -6 type (most notably Ektachrome and Fujichrome) and 2. K - 14 type (Kodachrome).

Both are based on the integral tri-pack.

Ektachrome is a reversal chromogenic color film which utilizes dye couplers within the emulsion layers. By contrast, the composition of Kodachrome is such that it does not contain dye couplers within the film. Rather, the dyes are introduced to the film during development. This development process, K - 14, is complex, requires expensive processing equipment and must be closely monitored. In the U. S. A., there are only a few laboratories that can process Kodachrome. As a consequence, there is a long time period between shooting and viewing Kodachrome transparencies.

E-6 type transparency materials are by far the preferred choice of image media for photographers, and art directors. The images are recorded in a clear polyester base without the textural problems inherent in reflected copy. Colors are faithfully recorded by three color dye layers whose spectral colors are considered extremely pure when compared to ink pigments. Unlike photographic prints, they are first generation originals created directly from the scene with only a single lens system. Processing is relatively simple and inexpensive.

Another reason E-6 type films are selected is that they allow the film to be "pushed". This is a technique where a low lighting situation requires the film speed to be increased. By underexposing and overdeveloping the film, the characteristic curve of the film is altered and may render an acceptable result. Such "pushing" is not possible with Kodachrome.

Finally, turnaround time for Ektachrome is 50 minutes from dry-to-dry. This makes it desirable when short deadlines are necessary. For these reasons, Ektachromes are the most common media used for color separations today.

Kodak Ektachrome 100 Professional film was used for this experiment. Its fine grain, high sharpness and resolution provided accurate image recording. The spectral sensitivities provided a good match to the selected source, electronic strobe. Further, it is intended for exposure between 1/10 second and 1/10,000 second, which correspond to the source. Finally, the shape of its characteristic curve includes a well defined toe, shoulder and straight-line section. This allows adequate manipulation of the useful log exposure range.

Processing: Film was processed with standard E-6 automatic processing methods. In order to insure accurate information about processing conditions, some measure of development was required. The degree of development directly affects the resulting density range of the transparency.

There are three principle measuring devices for degree of development.

1. Contrast index
2. Average gradient
3. Gamma

Contrast index is a useful measure of development contrast. It includes measures of the useful exposure range including part of the toe of the curve. For the method of measured photography, there is no exposure in this section of the curve, therefore, this was not as meaningful a measure of contrast as gamma for this experiment.

Average gradient is another measure of development contrast that is most useful when a straight line is not part of the characteristic curve. Since Ektachrome has a good straight line segment, this also was not appropriate.

Gamma is calculated from the straight line portion of the D-log H curve. "Gamma is considered to be an excellent measure of development contrast because it is the slope of the straight-line portion that is most sensitive to development changes."[1] Since exposures for measured photography are based around the center of the curve, for this experiment, it was the best measure of processing conditions.

Gamma was evaluated by measuring the reflection gray scale and plotting the results. This provided a good indication of the processing conditions which were essential to the results of the experiment.

It was found that the actual gamma was 1.8, although Kodak suggests a processing gamma of 1.7.

Format: 4" X 5" or larger format fulfilled all requirements for the test. Most importantly, it allowed accurate meter readings at the film plane. Also, the scanner operator could easily set up from this size in the determination of aim points. Furthermore, it is a standard used throughout the industry by studio professionals.

The format is compatible with available view cameras which allow the photographer extensive flexibility. Briefly, these include, the use of camera movements (lens and film plane) interchangeable lenses and long bellows extension.

Exposure: Optical flare cannot be eliminated from the camera and lens system. For this experiment, it was essential to minimize and account for it. Flare was minimized by 1. The use of a lens hood for all exposures. 2. Lenses were selected which had anti-reflective coatings, 3. The interior of the selected cameras were black and the bellows were pre-tested for light leaks, 4. Dirt and dust were kept to a minimum by thoroughly cleaning camera interior and lens before experimental exposures were made.

Finally, all exposures were determined at the film plane, using a small probe attached to an electronic strobe meter. In this way, the effects of flare were considered when illuminance ratios were calculated.

A detailed set of instructions was issued to the photographers with the assignment. An example is provided in Appendix A.

Metering: Camera exposures were determined using the calculated midtone reading from the film plane. This is a type of reflected light reading. "An objective method of arriving at the midtone reading is to take separate readings from the lightest and the darkest areas where detail is desired and to select a middle tone."[2]

Two groups of exposures were made using this technique. In the first, lighting was adjusted normally to an illuminance range of 6 to 8 stops; this represented the conventional exposure. (It is noted that this corresponds to 7.5 to 9.5 stops at the subject with an average of 1.5 stops of flare. Generally, a normal subject is considered to be approximately 7 stops.) In the second group, lighting was adjusted to reduce this range to 3.5 to 4.5 stops; this defined the transparencies made by measured photography and was calculated to correspond with the density range of the selected separation material and system.

Every attempt was made to ensure that other variables remain constant. The two conditions were exposed the same day to minimize variations; all metering was accomplished with the Sinar FCM flash meter and film plane probe attachment.

Lighting Equipment: A pre-requisite for this experiment was finding a good match between the spectral sensitivities of the film and the light source. Also, it was critical that the source be consistent in terms of color and output. For this reason, electronic flash was used.

The xenon filled electronic flash tube has a spectral energy distribution which is composed of many line peaks. These lines are very well distributed throughout the visible portion of the electromagnetic spectrum so as to give the appearance of a continuous source. Electronic flash has the equivalent color temperature of 5500 degrees K. This is reasonably close to the requirements for the selected film, Ektachrome, Type A (daylight). Film specifications are 5500 degrees K.

Electronic flash units are "consistent in color output and quantity of light output from flash-to-flash."[3]

Another key part of the lighting equipment included the reflector cards, fills and diffusion screens. Clean white bounce cards were essential so the color of the reflected light was not affected. Foamcore sheets were used; they had demonstrated this quality from previous experimentation.

Modification of the lighting was the factor controlling the density range of the image. As much as possible, all other variables were kept constant. Lighting ratios were altered by the control of the lighting equipment; diffusion screens were placed between the lights and the subject; reflection cards were placed just outside of frame; lights were added; light shields and baffles were placed strategically; output intensities were altered at the source. Using these controls, along with proper metering techniques, allowed the photographers to comply with the requirements of this experiment.

Separations: The scanner operator makes the decisions of tone compression. Upon examination of the original photograph, decisions are made concerning highlight, midtone and shadow placement. For the purpose of this experiment, it was necessary to reduce the subjective variables and to introduce a better means to control these subjective choices.

Each original included an overlay which clearly indicated two aim points. These were: a diffuse highlight where a highlight dot was placed, and a detail shadow, where a shadow dot was placed.

By specifying these two points, the subjective factors of tone compression were minimized. Both points were measured directly from the copy. So as to closely match the original transparency, these points were set up from the gray scale.

Separation Prints: "There are over one hundred possible press variables" that can affect a print. A press run was not necessary for this experiment. Instead, off-press proofs were made directly from the positive halftone separations. These proofs were made with the DuPont Cromalin system, a single sheet (integral) proofing method. The system was calibrated beforehand according to DuPont recommendations. The density range of Cromalin Commercial grade paper (at the R.I.T. lab) was determined experimentally to be 2.04. This figure is higher than that sighted in the example and for most lithographic printing conditions.

Final image size was 4" X 5".

Subjective Evaluations: "Quality is not a property of images, but a description of a judge's perception to images."[4]

All judgments were made according to specifications set forth by the American National Standards Association (ANSI) as outlined in the 1989 publication.[5] Briefly, these included a transparency illuminator and viewing booth having an illuminant equivalent to D50 (a correlated color temperature of 5000K.) The transparencies were mounted on a board equivalent in color to Munsell N5/. The reproduction prints were mounted on the same size board (six inches by seven inches) which was slightly lighter in value than the ANSI recommendation Munsell N8/. Provisions were made for viewing the two transparencies beside the two reflection prints in as close physical proximity as possible.

Ten experienced judges were selected from two target audiences...art directors, and photographers. Experienced judges were defined as those having a minimum of two years in a professional position where image judgments are part of the job description. Five experienced photographers and five experienced art directors were selected. Sample size was selected using the following criterion; alpha level of 0.05 and a maximum estimate of error of 30 %.

Thus,

n = 1/4 (Z - alpha/2 / E)squared ,

n = 1/4 (1.96 / 0.3)squared = 10.6

A set of instructions was read to each judge defining the qualities to inspect. A copy of these instructions is included in Appendix B. The pairs of images within each group were presented in random order. It was found that each judge required 8 to 15 minutes for the evaluations including instructions, questions and marking of the tally sheets. Appendix C exhibits a sample tally sheet.

Statistical analysis: The statistical analysis used for the data was the binomial chi square test of homogeneity, with an alpha level of 0.05.

Endnotes for Chapter V

1. Stroebel, L. et al., Materials and Processes of Photography, Focal Press, Boston, 1986, p. 49.

2. Stroebel, L. et al., Materials and Processes of Photography, Focal Press, Boston, p. 127.

3. Stroebel, L. et al., Materials and Processes of Photography, Focal Press, Boston, 1986, p. 219.

4. Evans, E. Experimental Research Methods and Strategies in Psychophysics of Image Quality, "Photographic Science and Engineers", # 22, March, 1978.

5. American National Standards Institute. "Color Prints, Transparencies and Photomechanical Reproductions - Viewing Conditions", American National Standards for the Graphic Arts and Photography, PH 2.30, April 26, 1989.

Chapter VI

ANALYSIS OF THE DATA AND CONCLUSION

Statistical Analysis:

The results of the judges' evaluations are shown in Table 1. The totals reveal that in answer to the experimental question, the judges selected the photographs made by measured photography more often than those by conventional photography. When asked which images represented a closer match between the transparency and the photomechanical reproduction print, they selected measured photography thirty-three times as opposed to seventeen times for conventional photography.

The binomial chi square test of homogeneity was used to determine if the difference represented a significant difference at the .05 alpha level.

Essentially, this test is used to determine if two samples, in this case, measured photography and conventional photography, are derived from the same population. Using the basic formula conceived by Frederick Helmert in 1876 and refined by Karl Pearson in 1900, the random variable, chi square, is calculated. Using the appropriate parameter v., degrees of freedom, and referring to standard statistical tables, the critical value is obtained. Finally, the critical value is compared to the test statistic. When the chi square test statistic is greater than the critical value of the degree of freedom, the null hypothesis is rejected.

Pearson's formula is:

Chi square = Sum of (Fo - Fe)squared / Fe

where Fo = frequency of the observation

and Fe = frequency of the expected results.

In the case of the judges' responses, the chi square calculations are displayed in Table # 2 and summarized in Table # 3.

These calculations reveal that the test statistic is greater than the critical value at the .05 alpha level of significance. This indicates that the populations are significantly different at this level and that the null hypothesis must be rejected. Consequently, this leads to the conclusion that the hypothesis is supported.

Table # 1

Results, Judges' Evaluations

Judge # 1.	C.P.	M.P.	C.P.	M.P.	C.P.
Judge # 2.	M.P.	M.P.	M.P.	C.P.	M.P.
Judge # 3.	M.P.	M.P.	M.P.	M.P.	C.P.
Judge # 4.	M.P.	C.P.	M.P.	M.P.	C.P.
Judge # 5.	C.P.	C.P.	M.P.	M.P.	M.P.
Judge # 6.	M.P.	M.P.	C.P.	M.P.	M.P.
Judge # 7.	M.P.	M.P.	C.P.	M.P.	C.P.
Judge # 8.	M.P.	M.P.	M.P.	C.P.	M.P.
Judge # 9.	C.P.	M.P.	M.P.	M.P.	C.P.
Judge # 10.	C.P.	C.P.	M.P.	M.P.	M.P.
TOTAL MEASURED PHOTOGRAPHY	6	7	7	8	5 TOTAL = 33
TOTAL CONVENTIONAL PHOTOGRAPHY	4	3	3	2	5 TOTAL = 17

Table # 2

Chi Square Calculations

	Fo	Fe	Fo - Fe	(Fo - Fe)^2	((Fo-Fe)^2)/Fe
M.P.	33	25	8	64	2.56
C.P.	17	25	-8	64	2.56
				CHI SQUARE =	5.12

Degrees of Freedom = (number of rows - 1) (number of columns) = (1) (1) = 1.

Critical Value at the .05 significance level = 3.841

Table # 3

Chi Square Analysis

	M.P.	C.P.
	33/50	17/50
	25/50	25/50
Fo =	33	17
Fe =	25	25

Test statistic = 5.12

Critical Value at the 0.05 level of significance = 3.841.

Summary and Conclusion:

The results of this research demonstrate that the hypothesis is supported by a clear margin; If a color transparency is made by measured photography, there is a closer visual match between the transparency and the separation print than between a conventionally made transparency and separation print. Also, measured photography allows a photographer to influence tone reproduction at the exposure stage. The implications of these findings are important to art directors, print buyers, photographers and others who stand to benefit from these methods. By rendering a better pre-visualization of the print from the transparency, measured photography may provide a better means of communication between the members of image reproduction teams. A major issue which demands further research, involves the economics of measured photography. This is outlined in Chapter VII.

The consensus among the group of photographers who made the transparencies, was that the metering technique was desirable, convenient, and accurate but that overall, it took considerably longer to make an image by measured photography. This may be one explanation why measured photography is not more widely utilized. On the other hand, the additional time required for measured photography may be reduced as a photographer becomes familiar with the technique and the equipment.

Another problem with the technique is the additional costs of the light metering equipment which includes the specialized meter, the film plane probe and the adaptor necessary for most cameras. An additional problem, an equipment failure, was the size of the aperture of the film plane probe which measures five millimeters. In some cases, this was too large an area to meter the primary highlight and/or shadow selections of the photographer. Finally, it was found that some color shifts may occur with the implementation of lighting alterations. This was probably more a function of light baffles and reflectors than the xenon light source.

The density ranges of the transparencies and the prints are summarized in Tables 4 and 5 in the appendix. From this, it is clear that objectively, as measured with a densitometer, the tonal range of the transparencies made by measured photography is closer to the tonal range of the prints. This supports the supposition that the photographer can control the tone compression at the exposure stage. The significance of this is that the photographer can better control the tone reproduction of his image throughout the printing process. The importance of this is self-evident to photographers who have made transparencies for reproduction.

It was found that there was no significant different difference between the photographers and the art directors in their selections. The five photographers (judges # 1 to #5), selected the measured photographs sixteen times whereas the art directors (judges # 6 to # 10), selected them seventeen times.

Within the group of photographers and art directors who served as judges, there was strong interest in measured photography. When the objectives of this research were explained to them after the evaluations, every judge, without exception, voiced a need for the opportunities provided through measured photography. Many of them cited examples from experience of miscommunication between the photographer and the color separator which resulted in "disaster" and might have been avoided had measured photography been utilized.

This thesis represents a detailed, but germinal investigation of measured photography. It is clear, from the results, that further research is recommended concerning this important system of image reproduction. The following chapter discusses several aspects concerning measured photography which suggest additional research.

Chapter VII

SUGGESTIONS FOR FURTHER RESEARCH

1. One of the purported benefits of measured photography is the increased exposure latitude it provides the photographer. The consequence is that it allows a photographer to reduce the number of bracket exposures and thereby yields a reduction of film costs. This is a powerful issue since it might convince economically minded photographers to seriously consider measured photography. Although the stipulation is theoretically sound, this theory should be scientifically verified as it relates to measured photography. It is recommended that such research be initiated to determine its validity.

2. Another purported benefit of measured photography is the increased opportunity for gang scanning groups of transparencies. It has been presumed that the reduced tonal range of the images might allow a scanner operator to preset the scanner, mount the transparencies conventionally and to gang scan the images. Initial indications from this research indicate that this may not be entirely valid. Transparencies made by measured photography which carry identical density ranges may have different density

levels for the range of tones between diffuse highlights and detail shadows. If such transparencies are gang scanned, they result in prints that are inconsistently and improperly exposed. Nevertheless, set-up time might be reduced since once the highlight is set, it is not necessary to set the range.

3. These issues lead to another question about measured photography. Is it less time consuming to make an image by measured photography than one by conventional photography? This is primarily an economic consideration and the answer would provide real insight into the feasibility and desirability of measured photography.

4. As discussed in Chapter II, one method for controlling the density range of the original is with the use of a pre-flash or post-flash exposure. Although there are problems inherent with this approach (as outlined in Chapter II, page 13), an investigation of this exposure technique would provide valuable data to the existing body of knowledge.

5. Finally, examination of the images demonstrates that aesthetic differences exists between the conventionally

exposed images and those made by measured photography. It would be beneficial to determine judges' preference of the images made according to these methods. If it could be positively established that images made by measured photography were preferable to those of conventional photography, it would provide powerful incentive to photographers and art directors to utilize this approach.

Appendix A

Instructions to Photographers

SPECIFICATIONS:

Format: 4" X 5" or larger.

Film: Ektachrome 100 Professional, Type A.

Processing: E-6, standard conditions

Lighting: Electronic strobe

Filtration: As required to obtain neutral grays.

Subject: Background should be neutral, pastel or simple. A model should be included, your choice, male or female. Good flesh tones are important. A gray scale and color chart should be prominently displayed in the image. MacBeth, Kodak or other suitable color charts are acceptable. An object with memory color should be included and you may add other items to make a creative and interesting image as you see proper.

SPECIAL INSTRUCTIONS:

Flare: Flare is to be minimized by: the use of a lens hood for all exposures, lenses with anti-reflective coatings, black bellows, and clean lens and camera surfaces.

Metering and Exposure: Reflection meter readings are to be taken at the film plane. You are to select two critical points from the scene:

1. A diffuse highlight to carry detail.
2. A shadow which will carry detail.

You may chose these points as you determine, but you are to indicate them carefully on a Polaroid (or acetate overlay taken from the camera back).

Using these aim points, you will adjust the lighting to obtain two different exposures.

1. The range between the highlight and shadow will be 6 to 8 f-stops.
2. The range between the highlight and shadow points will be 3.5 to 4.5 f-stops.

It's important that the two images are the same except for the lighting ratios as measured at the film plane.

The transparencies and Polaroid (or acetate overlay) will be delivered to me immediately after exposure, along with an illustration of your lighting arrangement for each photograph.

Appendix B

Instructions to the Judges

Thank you for taking time to help with this important research.

Shortly, you will be presented with a series of two paired images. Each group will contain two pairs of images representing a transparency paired to a separation print. These will be clearly marked.

I'd like you to examine each pair of the group and respond to the following question:

Which one of the pairs represents a better match between the transparency and the separation print?

A tally sheet will be provided for you to mark your responses. Dust spots and minor print defects are to be ignored.

Please take your time and examine each pair carefully. At any time, if you have a question, please feel free to ask. Do you have any questions now?

Okay, let us proceed. Here is the first group.

Appendix C

Table # 4

Density Ranges of Transparencies

			Conventional	Measured
IMAGE # 1	Shadow	=	2.89	2.13
	Highlight	=	0.22	0.24
	Total	=	2.67	1.89
IMAGE # 2	Shadow	=	2.85	2.18
	Highlight	=	0.20	0.25
	Total	=	2.65	1.93
IMAGE # 3	Shadow	=	2.82	****
	Highlight	=	0.18	0.23
	Total	=	2.64	N.A.
IMAGE # 4	Shadow	=	2.80	2.26
	Highlight	=	0.23	0.34
	TOTAL	=	2.57	1.92
IMAGE # 5	Shadow	=	2.96	2.28
	Highlight	=	0.26	0.33
	TOTAL	=	2.70	1.95

*** = Image spot too small to meter

Appendix D

Table # 5

Density Ranges of Prints

			Conventional	Measured
IMAGE # 1	Shadow	=	2.13	2.12
	Highlight	=	0.15	0.10
	Total	=	1.98	2.02
IMAGE # 2	Shadow	=	2.06	2.10
	Highlight	=	0.20	0.16
	Total	=	1.86	1.94
IMAGE # 3	Shadow	=	2.01	****
	Highlight	=	0.17	0.14
	Total	=	1.84	N.A.
IMAGE # 4	Shadow	=	2.10	2.15
	Highlight	=	0.11	0.16
	Total	=	1.99	1.99
IMAGE # 5	Shadow	=	2.17	2.17
	Highlight	=	0.19	0.22
	Total	=	1.98	1.95

**** : Spot area too small to meter

Appendix E

Tally Sheet

Indicate in the spaces below which of the two pairs represents a closer match between the transparency and the print.

Pair # 1.

A .... ____

B .... ____

Pair # 1.

A .... ____

B .... ____

Pair # 3.

A .... ____

B .... ____

Pair # 4.

A .... ____

B .... ____

Pair # 5.

A .... ____

B .... ____

Appendix F

List of Equipment and Materials

1. Film: Ektachrome Professional 100, Type A, 4" X 5". Polaroid, 100.
2. Camera: Sinar View Camera with normal lens (210 mm.).
3. Film holders for 4 X 5.
4. Test targets: Macbeth Color Chart and Kodak 10 step reflection gray scales.
5. Seamless materials and background stands.
6. Light meter: Sinar FCM, film plane system with metering probe.
7. Lighting equipment: Electronic strobe
   Power packs, 3 or 4
   Lamp head units, 3 to 6
   Bounce cards
   Light baffles
8. Viewing booth for reflectance evaluations and transparency illuminator corresponding to ANSI standards.
9. Instructions to the judges and tally sheet.

Appendix G

General Reference

1. "On the Theory of Tone Reproduction with a Graphic Method for the Solution of Problems", Loyd Jones, Journal of the Society of Motion Picture Engineers, Vol 16, p. 568.

2. "Tone and Color Control in the Reproduction Process", W. L. Jones, TAGA 1954, p.48.

3. Materials and Processes of Photography, Stroebel, L. et al, Focal Press, 1986.

4. Dictionary of Photography, Stroebel, L. and Todd, Hollis, Morgan and Morgan, 1971.

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8. "Four Stop Photography for Publication", Simon Dumenco, Step-by-Step Graphics, September, 1989.

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10. American National Standards Institute, "Color Prints, Transparencies and Photomechanical Reproductions - Viewing

Conditions", American National Standards for the Graphic Arts and Photography, PH 2.30, April 26, 1989.

11. Back to Basics: Input Copy Can Be Measured", lecture series, Spectrum, 1987, (available on cassette tape).

12. An Optical Merit Function (SQF) which correlates with subjective image judgments", E. M. Granger, Photographic Science and Engineering, Vol 16, #3, May 1972, p.221.

13. Eastman Kodak Publication #E-27, Kodak Ektachrome 100 Professional Film.

14. Color Separation Techniques, Miles Southworth, Graphic Arts Publishing, Livonia, NY 1989.

15. Statistics for Research, Dowdy, S. and Wearden, Stanley, John Wiley and Sons, Inc. 1983.

16. Statistics, An Introduction, Rickmers, Albert and Todd, Hollis, McGraw Hill Book Co., 1967.

Figure # 1

Conventional Tone Reproduction

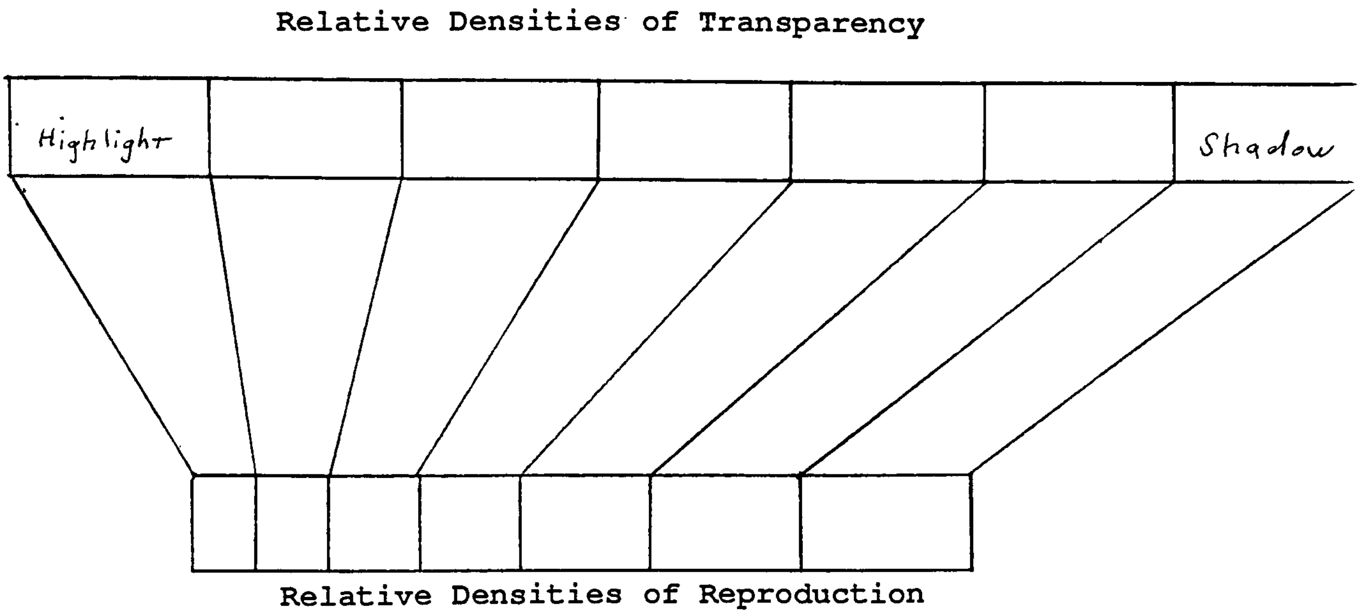

Figure # 2

Measured Photography Tone Reproduction

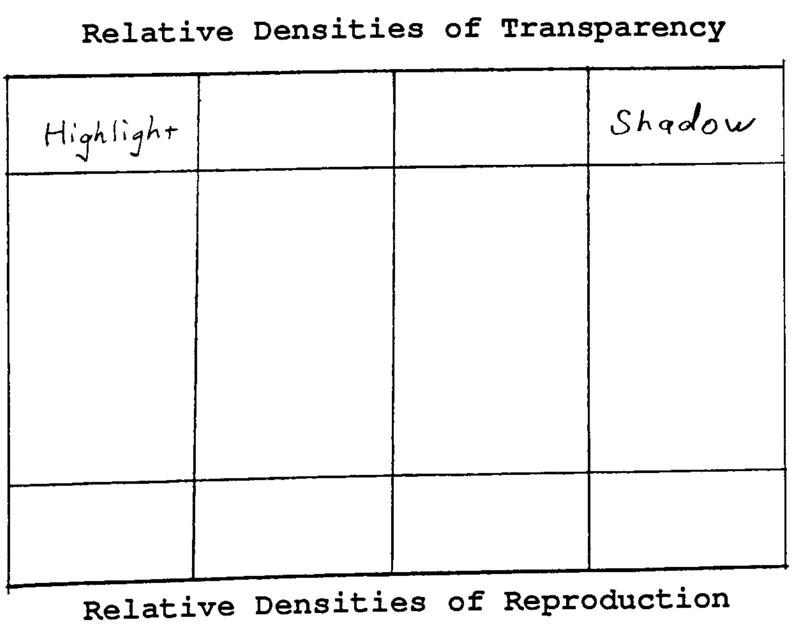

Figure # 1

Image # 1, Measured Photography

Figure # 2

Image # 1, Conventional Photography

Figure # 3

Image # 2, Measured Photography

Figure # 4

Image # 2, Conventional Photography

Figure # 5

Image # 3, Measured Photography

Figure # 6

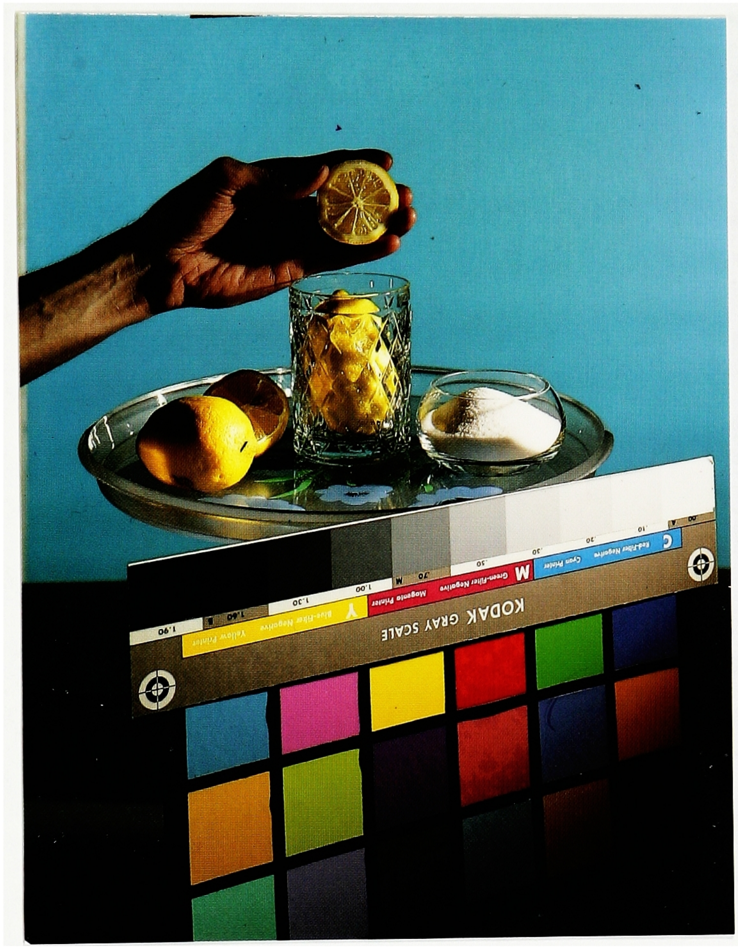

Image # 3, Conventional Photography

Figure # 7

Image # 4, Measured Photography

Figure # 8

Image # 4, Conventional Photography

Figure # 9

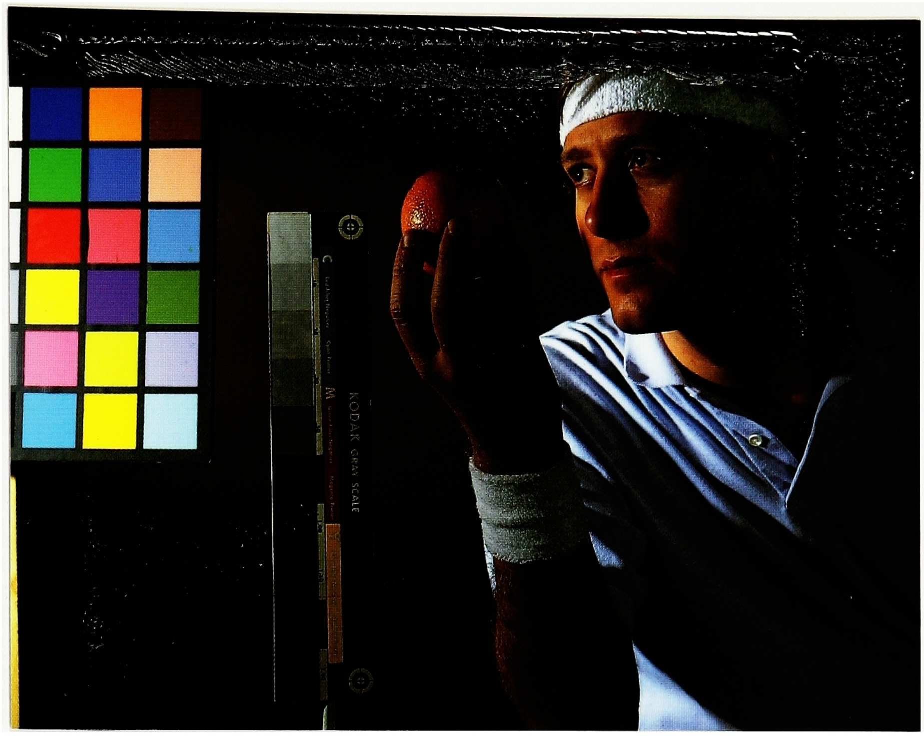

Image # 5, Measured Photography

Figure # 10

Image # 5, Conventional Photography